Dissociating orienting biases from integration effects with eye movements

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Abstract

Despite decades of research, the conditions under which shifts of attention are facilitated or inhibited to prior target locations remain unknown. This ambiguity is a product of the popular feature discrimination task, where attentional bias is commonly inferred from the efficiency by which a stimulus feature is discriminated, having repeated or changed its location. Problematically, these tasks lead to integration effects; target location repetition effects appear to depend entirely on whether the target feature or response also repeats, equivocating inferences about orienting bias. To parcel out integration effects and orienting biases, the experiments here require eye movement localization and then manual discrimination responses to serially-presented targets, which randomly repeat locations. Eye movements reveal consistent biases away from prior target locations. Manual discrimination responses reveal integration effects. These data collectively reveal inhibited re-orienting and integration effects, which resolves the ambiguity and reconciles episodic integration and attentional orienting accounts.

Under what conditions is a return shift of attention facilitated or inhibited to a prior target location? Despite decades of research, and countless studies, this fundamental question remains unsolved. A major reason for this is that the reaction time (RT) data that are typically taken as evidence of orienting bias in leading paradigms are strongly affected by perceptual processing demands. This often makes it extremely difficult to unambiguously distinguish attentional orienting biases from later processes involved with determining target identity (Posner & Petersen, 1990) and the response to it (Hommel, 1998).

Let's start with the simplest cases. In the common target-target detection and localization task, serially-presented target stimuli are simply detected or localized with button press responses. RTs are slower when target stimuli randomly repeat instead of switch locations, an effect that lasts for several seconds (e.g., Maylor & Hockey, 1985; Tanaka & Shimojo, 1996; 2000; Taylor & Donnelley, 2002; Welsh & Pratt, 2006). This is called inhibition of return (IOR). As implied by the name, IOR is widely thought of as a bias against shifting attention to previously attended regions (Posner, Rafal, Choate & Vaughan, 1985; Klein, 2000), which promotes efficient exploration of the visual environment (Wang & Klein, 2010).

The patterns become more complex in these same target-target paradigms when target identities are instead discriminated. In these cases, if the second target response repeats the first, RTs are faster, or facilitated, when target location repeats. In contrast, if the second target response is different than the first, RTs are slower, or inhibited, when target location repeats (e.g., Terry, Valdes & Neill, 1994; Notebaert & Soetens, 2003; Hommel, 2005; Rajsic, Bi & Wilson, 2013; Hilchey, Rajsic, Huffman & Pratt, 2017a; 2017b). These opposing facilitatory and inhibition effects are roughly symmetrical, making it unclear whether shifts of attention are biased in favor of (Tanaka & Shimojo, 1996) or against (Taylor & Donnelley, 2002) prior target locations.

Indeed, implicit episodic retrieval frameworks (Wilson, Castel & Pratt, 2006), like the Theory of Event Coding (TEC; Hommel, Musseler, Aschersleben, & Prinz, 2001; Hommel, Proctor & Vu, 2004), are ideally suited to alternatively account for the facilitatory and inhibitory patterns. These frameworks suggest that a target location and its response bind together to form a common representation, called an 'event file', that is

stored in implicit episodic memory. When a second target appears, a conflict occurs when it retrieves codes partially mismatching the prior event, which delays responding (Hommel, 2004). Results in line with these frameworks are often called integration or binding effects, in principle because costs come from integrating the target into the old event's representation. Applied to popular feature discrimination tasks, the TEC asserts that responses are facilitated by roughly equal amounts when both the prior target location and the prior response either repeat or switch relative to when only the prior target location or prior response repeats (i.e., integration effects or costs). This is precisely the pattern that occurs in these feature discrimination tasks. Whereas orienting biases cannot be ruled out by such findings, they are rendered entirely hypothetical because the results can be accounted for in full by the TEC (Hilchey et al., 2017a; 2017b).

As it stands, there is no unambiguous evidence of orienting biases when feature discrimination responses are made to targets. This is surprising given the maturity of the research area but also because orienting is often for the purpose of obtaining a meaningful, actionable percept. In this report, this long-standing ambiguity is resolved by requiring both eye movement localization and manual feature discrimination responses to targets. Our rationale for this approach and its success hinges on several key notions: (1) integration effects are a type of 'prepared reflex' (Hommel, 2005), brought on by feature discrimination (Hilchey et al., 2017a; 2017b), (2) integration effects are confined mainly to the responses involved with making discrimination judgments, similar in principle to distractor-response integration effects (Moeller, Hommel & Frings, 2015), and (3) integration effects can completely overshadow orienting biases (e.g., Klein, 2004).

With this approach, eye movements are functionally divorced from the arbitrary visuomotor transformations needed for the discrimination responses and are used only to orient. In principle, this makes the eye movements independent of the integration effects that obscure orienting biases. Consequently, eye movements should provide a relatively pure index of orienting bias, unlikely to be contaminated by integration effects. Manual RTs, on the other hand, should reveal roughly symmetrical target location repetition benefits and costs for manual response repeats and switches, respectively (i.e., integration effects). That is, on the basis of our previous work (Hilchey et al., 2017a; 2017b), we

expect no overall RT benefit or cost based on the repetition of target location. Thus, hypothetically, manual RTs will reveal integration effects with minimal evidence of orienting biases whereas the saccadic RTs will reveal orienting effects with minimal evidence of integration effects.

EXPERIMENT 1

Eye movements sample target locations and, when fixated, their identities ('x' or '+') are discriminated with manual responses. After the eye movement and manual response, the eye is summoned back from where it came and remains there until the next target appears randomly at either the same or different location as the first. Target location repetition effects are computed in the standard way, as the mean RT difference between target location repeats and switches. In some conditions, to help ensure that eye movements can only reflect orienting biases, we make target identities very difficult to see until fixated. In other conditions, we allow targets to be easily discriminable in the visual periphery, while still requiring eye movements to them for a trial to proceed.

Methods

Participants

The target sample size was 20 undergraduate students from the University of Toronto, but 24 participated for course credit. This was because four of the first 20 participants failed to comply consistently with the eye movement instructions (below). These participants made in excess of 5 eye movements on more than 30% of all trials (32%, 39%, 42% and 47%), a pass/fail criterion that was established prior to testing. Historically, the target sample size of twenty is more than adequate for detecting integration effects in manual RT data (e.g., Hilchey et al., 2017a; 2017b) and orienting biases in eye movement RT data, presuming inhibited re-orienting (e.g., Hilchey, Klein & Satel, 2014; Hilchey, Klein & Ivanoff, 2012).

Apparatus and Stimuli

Eye movements were monitored by an EyeLink 1000 Desktop Mount eye tracker (SR Research) with a temporal resolution of 1000 Hz and spatial resolution of 0.01° of visual angle. The velocity and acceleration thresholds for eye movements were set to 35.0°/sec and 9500.0°/sec^2. Stimuli were displayed on an 18" Dell P992 CRT monitor with a refresh rate of 85 Hz and 1024 x 768 pixels resolution. The stimulus display was connected to a 2.8 GHz dual-core processor while the eye tracker was connected to a 2.93 GHz dual-core processor. Head position was stabilized by a chin/head rest 57 cm from the monitor. Standard 9-point calibration and validation procedures were used until the average measurement error on gaze position was within half a degree of visual angle. Keypress responses were made using the spacebar (thumb), 'y' (right index finger) and 'b' (left index finger) keys on a standard QWERTY keyboard.

All stimuli were displayed against the black (RGB: 0, 0, 0; luminance: 3 cd/m^2) background of the CRT monitor. Placeholders were gray (RGB: 128, 128, 128; luminance: 31 cd/m^2) outline boxes subtending 2.0° x 2.0° of visual angle. One placeholder appeared at the center of the monitor and was flanked on the left and right by a placeholder 7.5° away, center-to-center. The white (RGB: 255, 255, 255; luminance: 84 cd/m^2) fixation cross subtended .3°x .3° and appeared in the center placeholder. In the 'target visible condition', target stimuli were white X's and +'s subtending 1.5°. In the 'target invisible condition', target stimuli were white small outline (2 pixel width) circles (radius = .24°) that circumscribed X's and +'s. Targets appeared in the center of placeholders. The main difference between conditions is that the X was very difficult to discriminate[1] from the + unless the observer made an eye movement to it in the 'invisible' condition, though the identity was not strictly gaze-contingent. The cue-back was a filled white circle (radius = .25°) in the middle of the center placeholder.

Procedure

See Figure 1 for general methods. Each trial began with the presentation of three placeholders and the fixation cross. To begin the trial, the observer performed a drift

[1] Pilot data showed that the 'invisible' targets were very difficult to discriminate from fixation, but not impossible with some effort and prolonged exposure durations.

correction by staring at the fixation cross and pressing the spacebar. A successful drift correction was signaled by a tone, and a half second later a target appeared randomly in the left or right placeholder. The observer made an eye movement to the target and, upon arriving, discriminated its identity by making a 'y' or 'b' keypress response for + or X targets, respectively. When the eye was within 3° of visual angle of target center and a keypress was recorded, the target vanished. After this, the observer returned their gaze to center, which was highlighted by the fixation cross' transforming into a cue-back. When this return eye movement was within 3° of visual angle of center, the cue-back transformed into a fixation cross. The observer refrained from making eye movements until the appearance of the next target, which occurred one-second later. This target appeared randomly in the left or right placeholder and was randomly either the same or different form as the first. An eye movement was made to this target and its form was discriminated with a keypress. When the eye was within 3° of visual angle of a target and a keypress response was recorded, all stimuli vanished from the screen, ending the trial. If a keypress error occurred at any point during the trial, at the end of the trial an error message appeared with the stimulus-keypress mappings. If more than five eye movements were detected on any given trial, that trial was spontaneously aborted with the removal of all stimuli and the message "You have made too many eye movements". These messages were acknowledged by pressing the spacebar. Between every trial, there was a 1 s interval during which no stimuli were onscreen.

Prior to this experiment, observers were informed correctly that the locations and identities of successive targets were uncorrelated. They were further instructed that a maximum of five eye movements were permitted on each trial, that an eye movement was required to each stimulus, that a blink counted as one eye movement and that only three eye movements were needed on each trial. They were further instructed that they could take breaks as necessary between trials, performing the drift correction at their leisure. Each observer first watched the experimenter (MDH) complete about a dozen trials successfully, after which the experimenter watched the observer practice for twenty trials and answered questions. Each observer then independently completed two consecutive blocks (80 experimental trials each) in each target visibility condition (320

total trials). Either two visible or invisible target-target blocks were administered first, and the order was counterbalanced across observers.

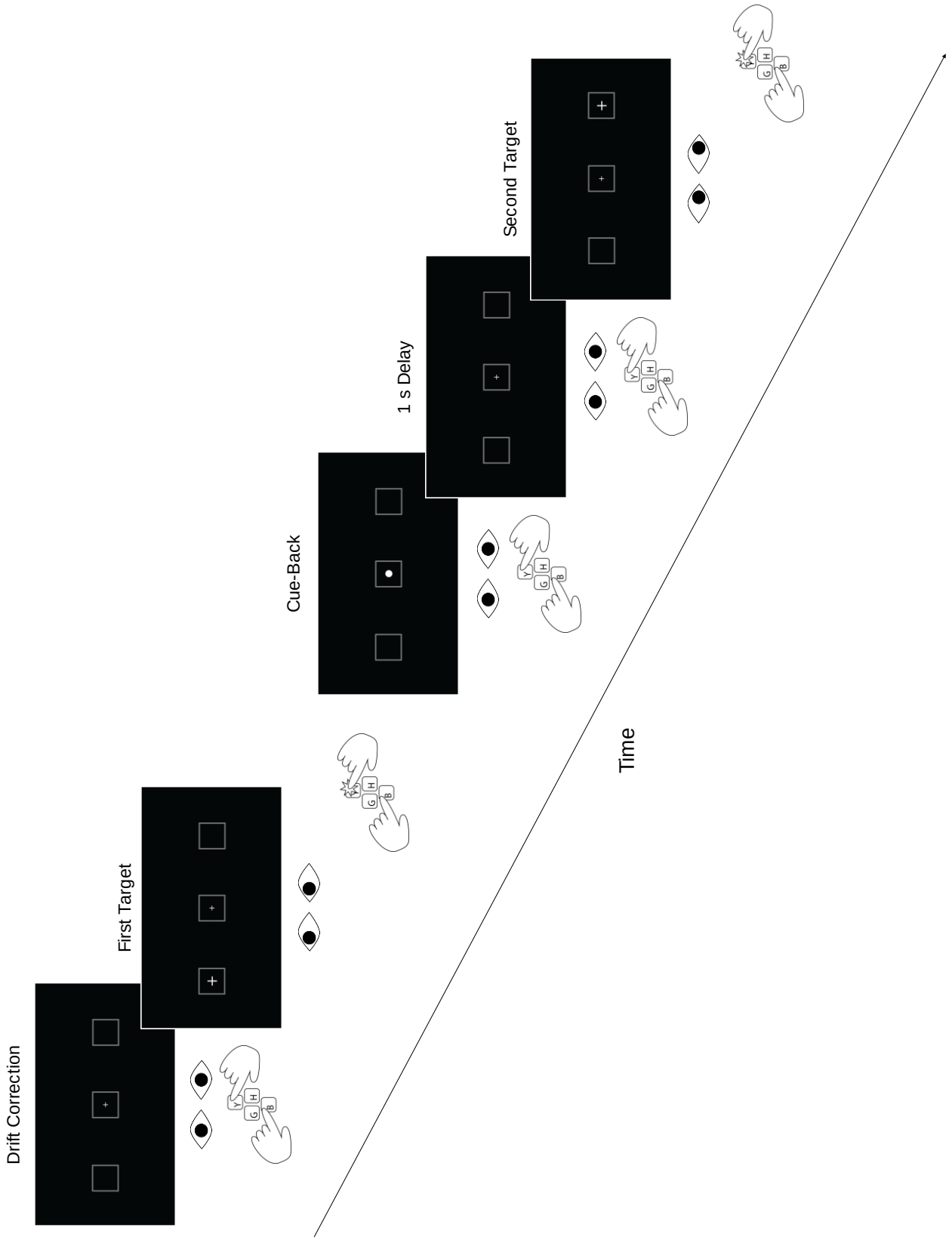

Figure 1. A possible sequence of trial events. In this case, the target location switches, with the eyes orienting to a new location and the manual discrimination form and response repeating.

Results

17.5% of the trials were excluded because more than 5 eye movements occurred. Seven trials were excluded for unreasonably long (> 5 s) target-target onset asynchronies. Of the remaining data, 8.0% of the total trials were removed due to keypress errors to either the first target (2.6%), second target (4.7%) or both (0.7%). 3.7% were excluded because gaze was not within 3° of center fixation when a target appeared. 4.5% were excluded because the first eye movement following a target did not land within 3° of it. 1.6% of trials were lost because a keypress was made to a target before an eye movement.

Saccadic reaction times (SRTs) were computed as the time between the onset of a target and the initiation of the first eye movement to it. Trials (0.4%) with impossibly fast target saccades (<80 ms) were excluded. Z-scores for SRTs were then computed for each participant for each condition (visible and invisible) to detect outliers (z-scores > 3) to the targets. 1.2% and 1.4% of trials were excluded as outliers for the visible and invisible conditions, respectively. Manual reaction times (MRTs) were computed as the temporal difference between the onset of a stimulus and the manual response. Z-scores for MRTs were then computed for each participant. 1.2% of trials were excluded as outliers (z-scores > 3) in each condition.

SRTs

Mean SRTs to the first target were 171 and 187 ms for invisible and visible targets, respectively. Mean SRTs to the second target were analyzed with a 2 (Target Location Repetition: repeat or switch) x 2 (Target Form Repetition: repeat or switch) x 2 (Condition: visible or invisible) repeated measures ANOVA (see Figure 2A). Critically, there was an effect of Target Location Repetition, $F(1, 19) = 63.88$, $p < 0.001$, $\eta_p^2 = 0.771$, with slower SRTs for target location repeats (196 ms) than switches (175 ms). There was also an effect of Condition, $F(1, 19) = 9.655$, $p = 0.006$, $\eta_p^2 = 0.337$, with faster SRTs for invisible (172 ms) than visible (199 ms) targets. There was no effect of Target Form Repetition, $F(1, 19) = 1.451$, $p = 0.243$, $\eta_p^2 = 0.071$.

Target Location Repetition interacted with Condition, $F(1, 19) = 6.399$, $p = 0.020$, $\eta_p^2 = 0.252$. While repeating target location led to slower SRTs in both Conditions, this slowing was greater for visible (M = 27 ms, 95% confidence interval = [18 - 36]) than invisible (M = 14 ms; 95% confidence interval = [7 - 20]) targets (see Figure 2A, compare between columns). Finally, there was an interaction between Target Location Repetition and Target Form Repetition, $F(1, 19) = 4.540$, $p = 0.046$, $\eta_p^2 = 0.193$. Repeating target locations led to slower SRTs when target form target form switched (M = 24 ms, 95% confidence interval = [18 - 30]) instead of repeated (M = 17 ms, 95% confidence interval = [10-24]; see Figure 2A, compare between form repeat and switch). No remaining interactions were reliable ($F < 1$). Ultimately, the data reveal inhibited re-orienting, despite some weakening of the effect by less visible targets and target form repetition.

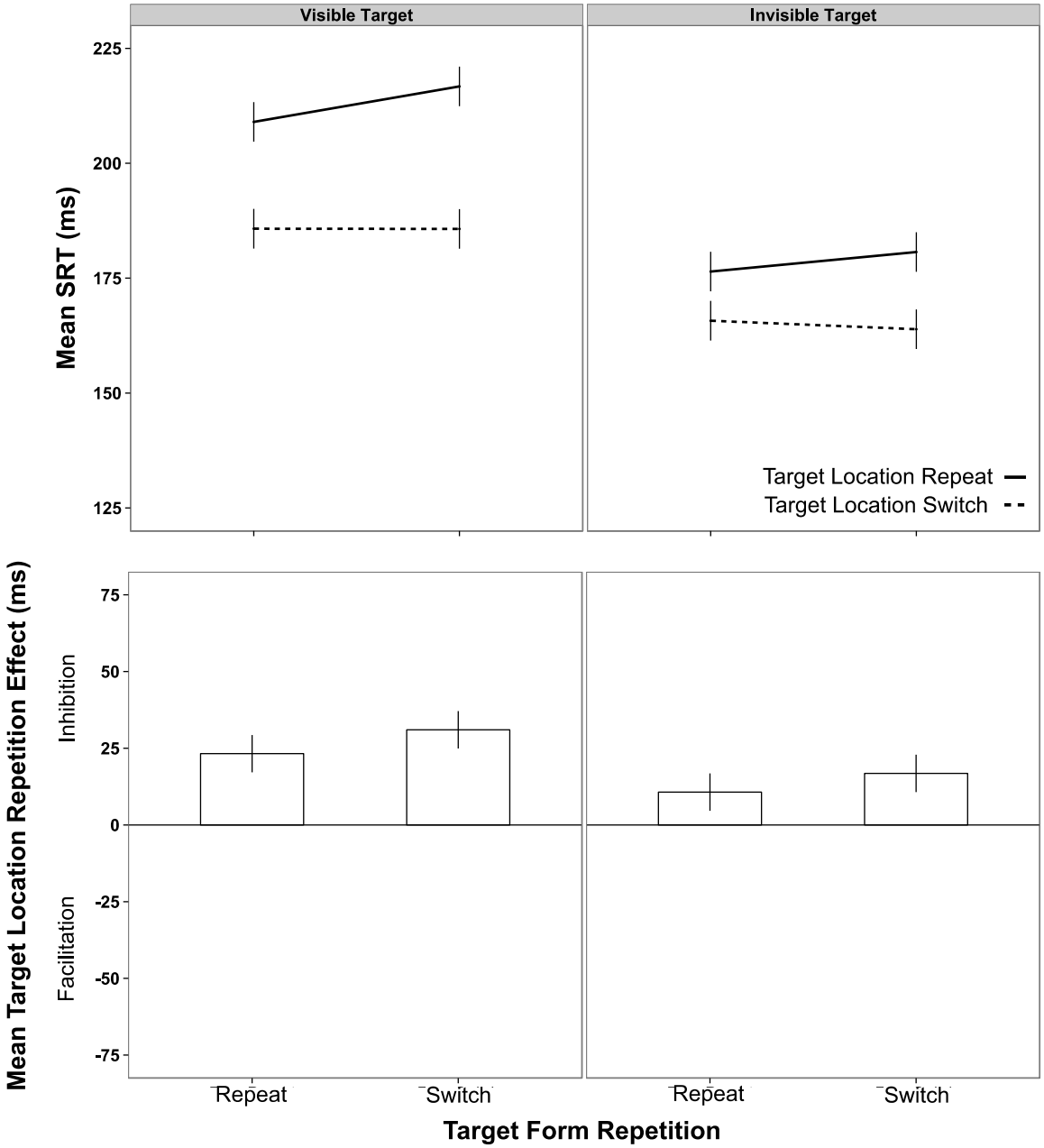

Figure 2A, top panels. Mean saccadic reaction times (SRTs) for all combinations of Target Location Repetition (line type) and Target Form Repetition (x-axis) in Experiment 1 for visible (left panels) and invisible (right panels) targets. *Bottom panels.* Mean SRT differences between target location repeats and switches (repeat RT – switch RT) across levels of Target Form Repetition (x-axis) and target Condition (columns). All errors bars are half Fisher's least significant differences (LSDs) computed from the mean squared error term of the three-way interaction. Non-overlapping error bars reveal significant simple effects.

MRTs

Mean MRTs to the first target were 877 and 672 ms for the invisible and visible targets, respectively. Mean MRTs to the second target were analyzed with a 2 (Target Location Repetition: repeat or switch) x 2 (Target Form Repetition: repeat or switch) x 2 (Condition: invisible or visible) repeated measures ANOVA (see Figure 2B). There was no effect of Target Location Repetition, $F(1, 19) = 0.459$, $p = 0.506$, $\eta_p^2 = 0.024$, and, thus, no unambiguous evidence of orienting bias. Target Form Repetition was significant, $F(1, 19) = 26.01$, $p < 0.001$, $\eta_p^2 = 0.578$, with faster MRTs when the target form repeated (708 ms) instead of switched (732 ms). The effect of Condition was significant, $F(1, 19) = 137.7$, $p < 0.001$, $\eta_p^2 = 0.879$, with faster MRTs for visible (626 ms) than invisible (813 ms) targets.

Critically, there was an interaction between Target Location Repetition and Target Form Repetition, $F(1, 19) = 46.38$, $p < 0.001$, $\eta_p^2 = 0.709$, which reveals that fully repeating or switching the prior target location and form led to the fastest MRTs (see Figure 2B), which are the standard integration effects. No other interactions were reliable (Fs < 1) and none of the MRT effects were undermined by speed accuracy tradeoffs.

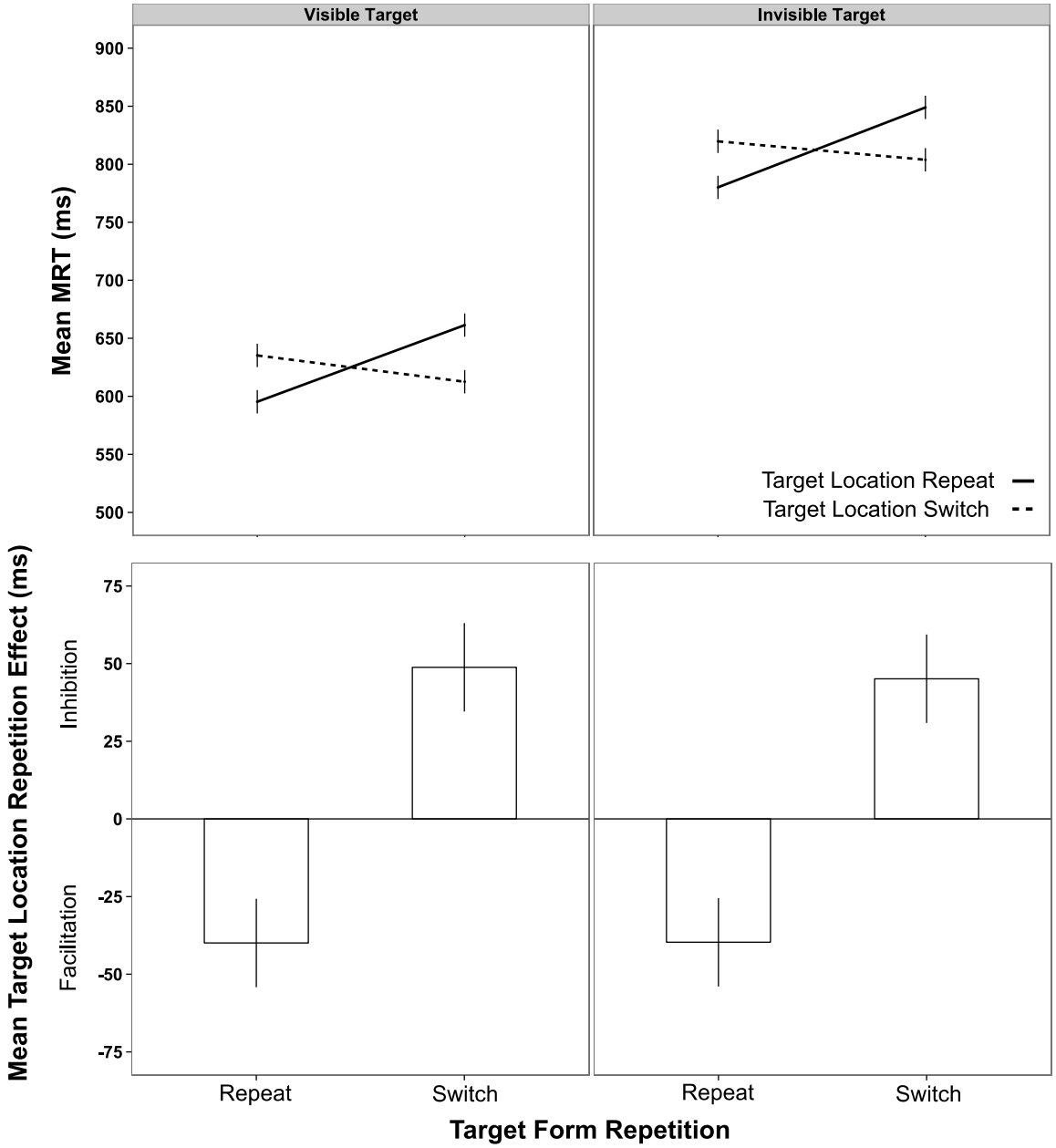

Figure 2B, top panels. Mean manual reaction times (MRTs) for all combinations of Target Location Repetition (line type) and Target Form Repetition (x-axis) in Experiment 1 for visible (left panels) and invisible (right panels) targets. *Bottom panels.* Mean MRT differences between target location repeats and switches (repeat MRT – switch MRT) across levels of Target Form Repetition (x-axis) and target Condition (columns). All errors bars are half Fisher's least significant differences (LSDs) computed from the mean squared error term of the three-way interaction. Non-overlapping error bars reveal significant simple effects.

Discussion

The SRT data decisively demonstrate that attentional orienting is biased against a prior target location, without much evidence of integration, despite some weakening of this orienting bias by less visible targets and form repetition. In contrast, the MRT data decisively demonstrate integration effects, with faster responding when both target location and form/response repeated or switched, without much evidence of orienting bias.

EXPERIMENT 2

Although there was compelling evidence for integration in the MRTs and inhibited re-orienting in the SRTs of Experiment 1, the data loss, in combination with a couple of small and unanticipated effects in the SRT data, compelled us to firm up and extend these findings. The main difference here is that targets also randomly vary on a response-irrelevant dimension (color: red or green). In the MRT data, this should reveal an additional integration effect, with the fastest MRTs occurring when the response-relevant form and response-irrelevant color both repeat or switch (e.g., Hommel & Colzato, 2004). As for the eye movements, although there is little indication that integration effects should factor into the orienting biases, we wanted to give a salient dimension, like color (Huffman, Al-Aidroos, & Pratt, 2017), an opportunity to do so, while also re-evaluating whether the relatively small effects of target visibility and form repetition on the orienting bias were reliable.

Methods

Participants

The target sample size was 20 undergraduate students from the University of Toronto, to match Experiment 1. But 25 students participated for course credit. This was because five of the first 20 participants failed to meet the inclusion criterion, making in excess of five eye movements on over 30% of all trials (31%, 33%, 34%, 42% and 45%).

Apparatus and Stimuli

Same as in Experiment 1, except the 'x' and '+' targets were randomly red (RGB: 225, 0, 0; luminance: 30 cd/m^2) or green (RGB: 0, 125, 0: luminance: 30 cd/m^2).

Procedure

Same as in Experiment 1 with two exceptions. One, observers were also explicitly instructed to ignore the target color as it was irrelevant and uncorrelated with target locations and forms. Two, the trial count for each block was increased to 128 (256/condition) to accommodate target color repetition as a factor.

Results

15.9% of their trials were excluded because more than 5 eye movements occurred. Three trials were excluded for unreasonably long (> 5 s) target-target onset asynchronies. Of the remaining data, 6.8% of the total trials were removed due to keypress errors to either the first target (1.9%), second target (4.4%) or both (0.5%). 3.2% were excluded because gaze was not within 3° of center when a target appeared. 3.9% were excluded because the first eye movement following a target did not land within 3° of it. 1.7% of trials were lost because a keypress was made to a target before an eye movement.

Trials (0.4%) with impossibly fast target saccades (<80 ms) were excluded. Z-scores for SRTs were then computed for each participant for each condition (visible and invisible) to detect outliers (z scores > 3) to the targets. 1.4% and 1.3% of trials were excluded as outliers for the visible and invisible conditions, respectively. Z-scores for MRTs were then computed for each participant. 1.1% and 1.0% of trials were excluded as outliers (z-scores > 3) in the visible and invisible conditions, respectively.

SRTs

Mean SRTs to the first target were 159 and 172 ms for the invisible and visible targets, respectively. Mean SRTs to the second target were analyzed with a 2 (Target Location Repetition: repeat or switch) x 2 (Target Form Repetition: repeat or switch) x 2

(Target Color Repetition: repeat or switch) x 2 (Condition: visible or invisible) repeated measures ANOVA (see Figure 3A). Critically, and as before, there was an effect of Target Location Repetition, $F(1, 19) = 18.01$, $p < 0.001$, $\eta_p^2 = 0.487$, with slower SRTs for target location repeats (175 ms) than switches (157 ms). There was a marginal effect of Condition, $F(1, 19) = 3.807$, $p = 0.066$, $\eta_p^2 = 0.167$, with faster SRTs for invisible (158 ms) than visible (173 ms) targets. Neither the effect of Target Color Repetition nor Target Form Repetition was significant (both Fs < 1).

There were two marginally significant interactions. One of these concerned the relationship between Target Location Repetition and Target Form Repetition, $F(1, 19) = 3.51$, $p = 0.077$, $\eta_p^2 = 0.156$. Essentially, this was trending in the opposite direction of what was observed in Experiment 1, such that repeating target location led to slightly slower SRTs when the target form repeated (M = 20 ms; 95% confidence interval = [10-29]) instead of switched (M = 16 ms; 95% confidence interval = [8 – 25]; see Figure 3A, compare between form repeat and switch bars). This inconsistency between experimental results, coupled with the relatively small effect sizes, suggests that this interaction may be spurious. The other marginal interaction concerned the three-way among Target Form Repetition, Target Color Repetition and Condition, $F(1, 19) = 4.278$, $p = 0.0525$, $\eta_p^2 = 0.184$. In the invisible condition only, SRTs tended to be about 4 ms faster when both the prior color and form repeated or switched relative to when one feature remained the same and the other switched. No other interactions looked even remotely plausible (all ps > 0.10). The important point is that the data again reveal inhibited re-orienting across all conditions.

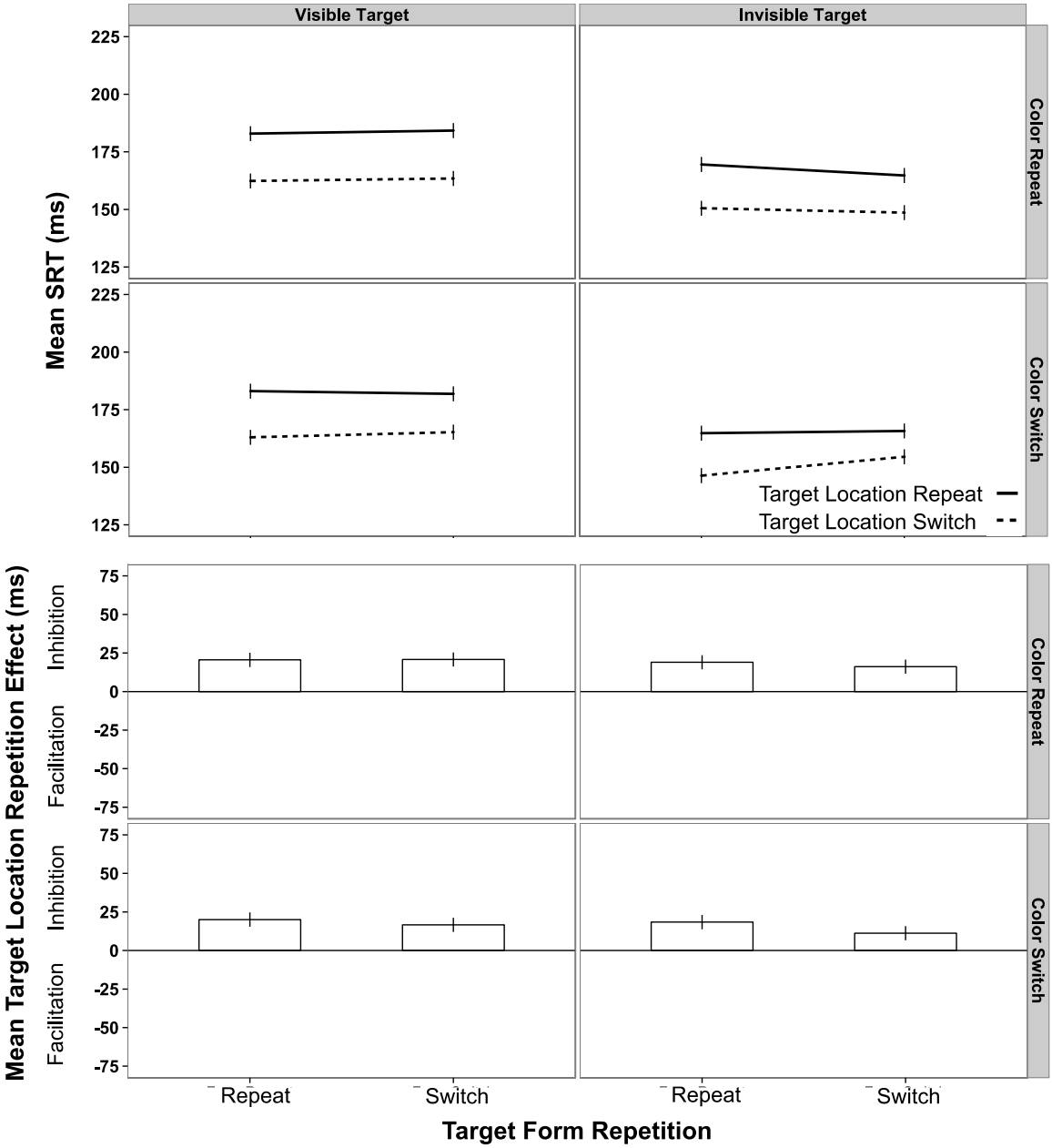

Figure 3A, top 4 panels. Mean saccadic reaction times (SRTs) for all combinations of Target Location Repetition (line type), Target Form Repetition (x-axis) and Target Color Repetition (rows) in Experiment 2 for visible (left column) and (right columns) invisible targets. *Bottom 4 panels*. Mean SRT differences between target location repeats and switches (repeat SRT – switch SRT) across levels of Target Form Repetition (x-axis), Target Color Repetition (rows) and target Condition (columns). All error bars are half Fisher's least significant differences (LSDs) computed from the error term of the four-way interaction. Non-overlapping error bars reveal significant simple effects.

MRTs

Mean MRTs to the first target were 803 and 617 ms for invisible and visible targets, respectively. Mean MRTs to the second target were analyzed with a 2 (Target Location Repetition: repeat or switch) x 2 (Target Form Repetition: repeat or switch) x 2 (Target Color Repetition: repeat or switch) x 2 (Condition: visible or invisible) repeated measures ANOVA (see Figure 3B). There were main effects of Target Form Repetition, $F(1, 19) = 7.051$, $p = 0.016$, $\eta_p^2 = 0.271$, Target Color Repetition, $F(1, 19) = 6.777$, $p = 0.018$, $\eta_p^2 = 0.263$, and Condition, $F(1, 19) = 157.6$, $p < 0.001$, $\eta_p^2 = 0.892$. MRTs were faster when target form repeated (657 ms) instead of switched (669 ms). MRTs were also faster when target color repeated (660 ms) instead of switched (666 ms). MRTs were faster for visible (574 ms) than invisible (753 ms) targets. There was a marginal effect of Target Location Repetition, $F(1, 19) = 3.884$, $p = 0.064$, $\eta_p^2 = 0.170$, with generally slower MRTs when target location repeated (667 ms) instead of switched (659 ms).

There were three reliable interactions. Target Location Repetition interacted with Target Form Repetition, $F(1, 19) = 41.96$, $p < 0.001$, $\eta_p^2 = 0.688$, which, as before, revealed that MRTs were relatively fast when both target location and form repeated or switched as compared to when only target location or form repeated (see Figure 3B, compare columns). Target Form Repetition interacted with Target Color Repetition, $F(1, 19) = 47.69$, $p < 0.001$, $\eta_p^2 = 0.715$, which revealed that MRTs were relatively fast when both the prior form and color repeated or switched relative to when only the color or form repeated. There was also a three-way interaction among Target Location Repetition, Target Color Repetition and Target Form Repetition, $F(1, 19) = 8.816$,, $p = 0.008$, $\eta_p^2 = 0.317$. Generally stated, the relative RT advantages for full binary (e.g., location and form, or color and form) repetitions and switches were strongest when a third dimension (e.g., color or location, respectively) also repeated. These are standard integration effects.

Finally, there was one marginal interaction between Target Color Repetition and Condition, $F(1, 19) = 4.231$, $p = 0.054$, $\eta_p^2 = 0.182$, such that color repetition led to generally faster RTs in the invisible condition (12 ms) than in the visible condition (1 ms) but this effect, if present, is very weak. No other relationships were significant (all *p*s > .10) and no MRT effects were undermined by speed accuracy tradeoffs.

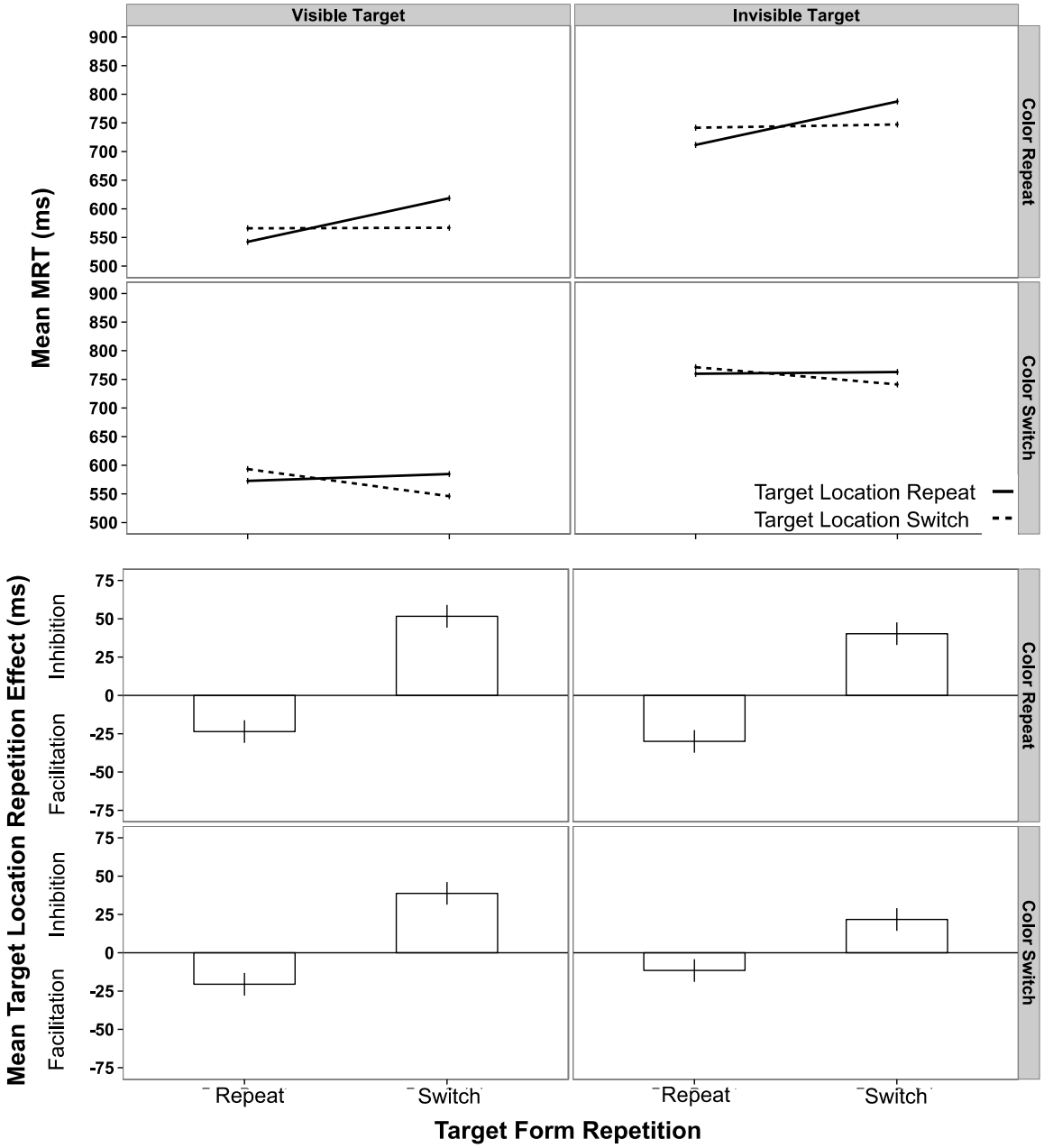

Figure 3B, top 4 panels. Mean manual reaction times (MRTs) for all combinations of Target Location Repetition (line type), Target Form Repetition (x-axis) and Target Color Repetition (rows) in Experiment 2 for visible (left column) and (right column) invisible targets. Errors bars are half Fisher's least significant differences (LSDs) computed from the mean squared error term of the four-way interaction. *Bottom 4 panels.* Mean MRT differences between target location repeats and switches (repeat MRT – switch MRT) across levels of Target Form Repetition (x-axis), Target Color Repetition (rows) and target Condition (columns). All error bars are half Fisher's least significant differences

(LSDs) computed from the error term of the four-way interaction. Non-overlapping error bars reveal significant simple effects.

Discussion

The SRT data again revealed impressively stable orienting biases against the prior target location, largely unaltered by any other higher order interactions. Any effect of repeating a target feature on this orienting bias was weak, unreliable, and in no way undermined inhibited re-orienting. In contrast, the MRT data showed standard integration effects between form and color, and form/responding and location, which were amplified by repetition of a third dimension (see also, e.g., Hommel & Colzato, 2004). There was only weak to non-existent evidence of orienting bias in the MRTs.

GENERAL DISCUSSION

These data unambiguously establish inhibited re-orienting in feature discrimination tasks, while also establishing that integration effects, as revealed by manual discrimination responses, can completely obscure this inhibition. The data also establish an important boundary on integration effects by revealing that they are confined mainly to responses involved in actualizing perceptual discrimination judgments. Our findings largely resolve ambiguity between episodic retrieval and attentional orienting frameworks in accounting for data from feature discrimination tasks by dissociating them within the same experiments, thereby validating both accounts.

Historically, because responding is slower to a prior target location only if a different response is made, there has been little unequivocal support for orienting biases in target discrimination tasks (Terry, Valdes & Neill, 1994; Taylor & Donnelley, 2002). This has led to justifiably stronger emphases on the role of episodic retrieval and updating processes in accounting for the MRT data (e.g., Hommel, Proctor & Vu, 2004; Lupianez, 2010). Simply put, the MRTs are particularly sensitive to processes related to making the perceptual judgment but much less so orienting bias. As shown here, a straightforward behavioral solution for distinguishing between enduring attentional

orienting biases and integration effects is to decouple orienting from the processes of enacting a perceptual judgment. Variations on this general idea could be implemented in many attention paradigms for which there is ambiguity about the status of attentional orienting biases and episodic retrieval processes (e.g., see Frings, Schneider & Fox, 2015; D'Angelo, Thomson, Tipper & Milliken, 2016, for reviews of spatial negative priming) or attentional orienting biases and later selection effects (see Lamy & Kristjansson, 2013, for a review of inter-trial priming).

In accounting for target location repetition effects in the SRT data here, the only reliable processes are related to IOR. Stimulus-elicited saccade priming or execution causes this and the effect goes on to bias later orienting toward novel regions (Posner, Rafal, Choate & Vaughan, 1985; Hilchey, Klein & Satel, 2014). For the MRT data, it is necessary to invoke processes related to implicit episodic retrieval and updating (Hommel, 2005; 2007). These processes are low-level heuristics that facilitate the re-enactment of prior perceptual judgments when aspects (e.g., location) of an earlier target repeat and that facilitate novel responses when aspects of an earlier target switch. To account for the absence of inhibited re-orienting in the MRT data, there are some possibilities. One is that the tendency to repeat the prior response when target location repeats is stronger than the tendency to alternate the prior response when target location switches. When inhibited re-orienting is added to this, it would result in the appearance of roughly symmetrical integration effects. A second possibility is that the response repetition and alternation tendencies for target location repeats and switches are roughly equal, in which case another process would be necessary to offset inhibited re-orienting. This third hypothetical process could be related to the facilitatory target location repetitions effect often reported in inter-trial priming studies that require focused attention (i.e., the need to narrow in on and select the particular identity of a stimulus, once found; Yashar & Lamy, 2010). Stated simply, it may be easier to re-engage focal attention to or extract information from a prior target location after re-orienting to it has occurred.

Ultimately, the present findings clearly dissociate orienting biases from integration effects by functionally divorcing oculomotor responding from manual feature judgments. Simply, there are unambiguous orienting biases against previously attended

locations in feature discrimination tasks when integration effects are factored out. These data reveal that inhibited re-orienting is a ubiquitous side-effect of prior oculomotor orienting, which can be completely overshadowed by integration effects. At the same time, the methods herein provide a powerful, and relatively intuitive, tool for dissociating attentional orienting biases from later effects related to episodic retrieval, updating and selection.

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